STK / SEET RADIATION ENVIRONMENT TUTORIAL

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Licenses Needed

This tutorial requires that you be licensed for the STK Space Environmental Effects Tool (SEET).

Introduction

The Radiation Environment component provides a suite of models for computing energetic particle fluxes and fluences in near-Earth space, as well as ionizing dose rates and integrated doses behind user-specified shielding thicknesses (dose-depth curves.) The flux models provided include the Air Force Research Laboratory (AFRL) CRRES models as well as the standard NASA AE8/AP8 models for both protons and electrons. For dose quantities, the data based APEXRAD and CRRESRAD models are provided, which give total dose only for a limited set of shielding thicknesses, as well as the standard SHIELDOSE-2 model, which is highly configurable in terms of, for example, shielding thickness and detector type, and can provide the dosing due to protons, electrons and bremsstrahlung separately. Starting with STK-SEET 9.2.3, computation with SHEILDOSE-2 has been sped up significantly by allowing the user to select a “Dose Integration Step” and “Dose Report Step”. With these parameters, fluxes are accumulated at the time-resolution specified by the Dose Integration Step for a period corresponding to the Dose Report Step, and then passed to SHIELDOSE-2 for dose computation. Speed-ups are on the order of Dose Report Step over orbit time-step, e.g., 1440 min/1 min = 1440 for an integration interval of 1 day and orbit time step of 1 minute (assuming Dose Integration Step = orbit time step, which is a reasonable choice.) Note, to obtain the previous behavior of the model, simply set both the Dose Integration Step and Dose Report Step equal to the scenario time step.

Since the models for this component are essentially climatological databases obtained by binning satellite data in a magnetic coordinate space (specifically, L_M and B/B_0), a particular magnetic field model must be specified in order to access the data. Here, L_M is the McIlwain L parameter, a mathematical way of indexing an energetic particle's drift shell, and B/B_0 is the ratio of the local magnetic field to the minimum magnetic field along the field-line passing through the local point in space. L_M and B/B_0 are computed internally

from the user-specified magnetic field model (see the STK / SEET Magnetic Field Tutorial and the SEET user manual for more information.)

Starting with STK-SEET 9.2.3, two additional options for setting the magnetic field have been added to the SEET Radiation tab (in the Satellite Basic Properties list) which provide additional compatibility with the SPENVIS radiation environment computation technique. These options are *"Set magnetic field epoch to Mode's reference epoch"* and *"Shift SAA using Mode's reference epoch"*. Note that when these settings are selected, the magnetic field model selections set in the Satellite Basic SEET Environment tab are ignored for the purposes of radiation environment computations. See the SEET User Manual for further information.

Problem Statement

For a given space vehicle configuration and orbit, determine: a low resolution data-based dose-depth curve for a long time base-line orbit (6 months); a high resolution model-based dose-depth curve for a long time base-line orbit (6 months) using flux integration; a min/max flux comparison on an intermediate time base-line orbit (single day.)

Getting Started

The primary decisions to make when developing a Radiation Environment scenario using STK involve determining which models to use and balancing accuracy or resolution of results versus computational speed.

- Decide which magnetic field model(s) to use. Low-Earth Orbits (LEO) under about 1500 km altitude generally do not require the external field model. Tilted-dipole is a good choice when computational speed is a high priority. IGRF main-field with Olson-Pfitzer gives the highest accuracy. Fast-IGRF is reasonably accurate (within 1% of IGRF) and intermediate in speed. Fast-IGRF with Olson-Pfitzer external is typically a good choice here in nearly all circumstances.
- Determine the optimal IGRF update rate. This determines how frequently the IGRF model coefficients are recomputed. The default of 1 day should be fine for most circumstances, but increasing it to up to 30 days for very long orbits can improve computational speed.
- Note that the field choice is pre-determined and set automatically when the *"Set magnetic field epoch to Mode's reference epoch"* option in the Satellite Basic SEET Radiation tab is selected.
- Decide which Radiation Environment models to use. APEXRAD, CRRESRAD or Radiation-only (APEXRAD except where out of range of that model, in which case CRRESRAD is used) are fast, data based models but with a limited range of shielding depths. They should be used for computationally fast high resolution dose rate computation over long orbits. However, for access to the full range of SHIELDOSE-2 options (selectable depths, different detector types, species-resolved doses, greater spatial range of validity), either the CRRES or NASA models must be selected. The NASA models cover the broadest spatial and energy ranges while the CRRES models are based on more recent data (1990s.) When

used in conjunction with large Dose Report Step sizes, these models can also provide computationally efficient high depth-resolution total dose-depth curves.

Solution Approach

Build a scenario that will cover the desired time period for the satellite orbit of interest. Add a ground station of interest. Set the relevant model parameters to achieve the desired balance between accuracy and computational speed. Configure STK properties as needed to obtain the desired display.

Create the Scenario

1. Create a new scenario by using the New Scenario Wizard, by selecting "New…" from the File menu, or by clicking the corresponding toolbar button . Fill in the scenario name and description. For the analysis period, enter 1 Oct 2009 00:00:00.000 UTCG to15 Oct 2009 00:00:00.000 UTCG. Click "OK" and save the new scenario.

2. Next, add a satellite to the scenario. We will use a nominal eccentric orbit that covers a large portion of the inner belt and a smaller portion of the outer belt, which will exercise the Radiation Environment models in the desired manner.

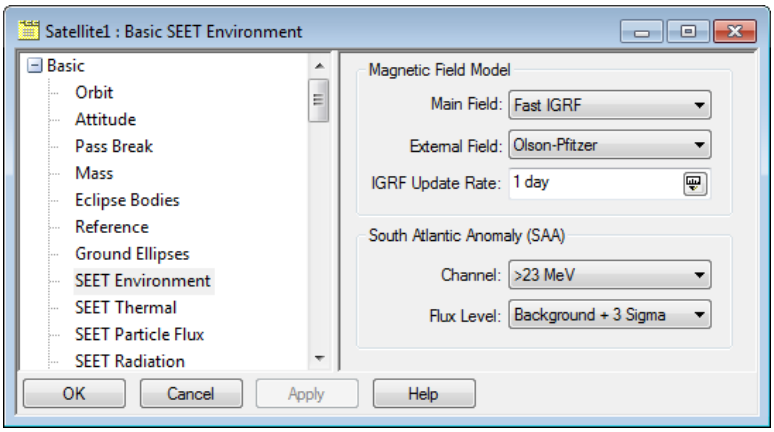
   Select menu *Insert: New*… Under "Scenario Objects", highlight "Satellite". Under "Select a Method", choose "Orbit Wizard". In the Orbit Wizard window, for "Type", select "Orbit Designer", then fill in the following values: Semimajor Axis: 15000 km; Eccentricity: 0.4; Inclination: 30 deg; Argument of Perigee: 50 deg; RAAN: 90 deg. Then click "OK".

3. Close the "Insert STK Objects" dialog box.

4. Right-click the scenario object in the Object Browser and select "Properties". Under "Basic", select "Units" then scroll down to RadiationShieldThickness and select "Millimeters (mm)". Returning to "Basic", select "SEET Radiation". In the *NASA Electron and Proton Activity* box, change the dialog to "Solar Max". Click "OK".

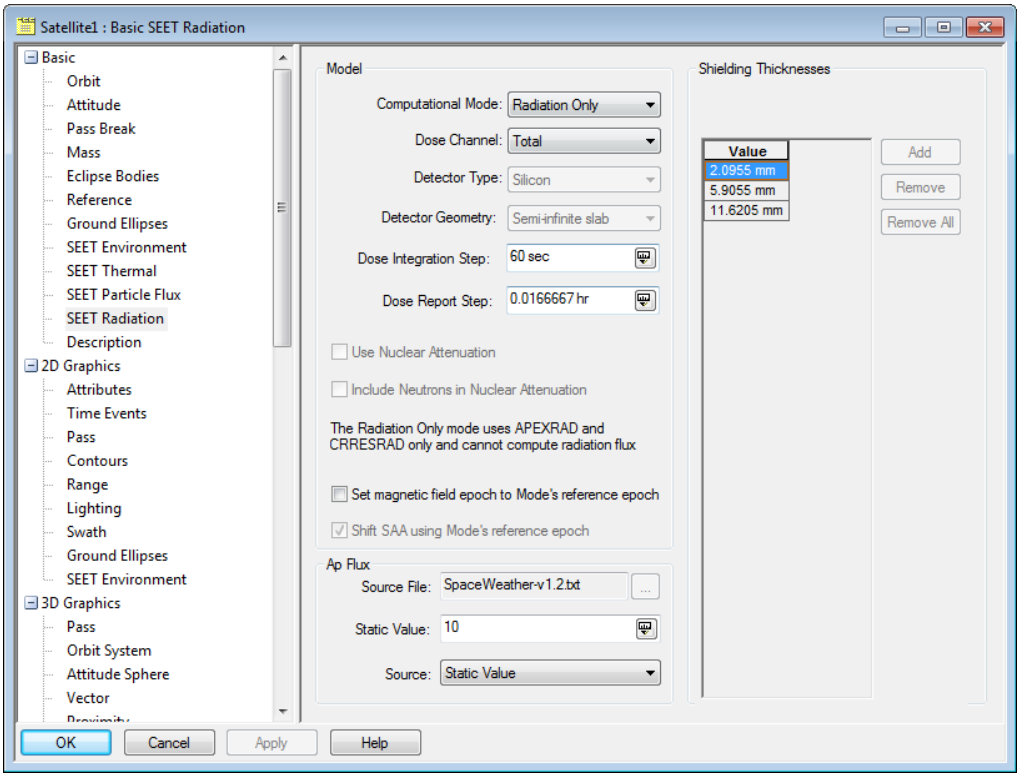
Configure the Magnetic Field model for use with the Radiation Environment models

5. Right-click on the satellite object in the Object Browser and select "Properties…". In the properties panel tree, under Basic, select "SEET Environment". The upper dialog box contains the magnetic field parameters. We will set these to the standard set for use with the Radiation Environment. Set the "Main Field" dialog to "Fast IGRF" and the "External Field" to "Olson-Pfitzer". Leave the "IGRF update rate" as it is and click *Apply*.



Configure the Radiation Environment for a long time base dose-depth analysis

6. Next we will configure the Radiation Environment for a long time base-line dose depth analysis and generate the corresponding report. Since these generally take very long to compute, we will use the data-based models. On the Satellite Properties page, under “Basic”, select “SEET Radiation”. In the Model box, verify that “Computational Mode” is set to “Radiation Only” and “Dose Channel” is set to “Total”. Set both the “Dose Integration Step” and the “Dose Report Step” to 60 sec and un-check the “Set magnetic field epoch…” box. Leave all other options at their default values, including the Shielding Thicknesses listed at the right. Note that in *Radiation Only*, *CRRESRAD* and *APEXRAD* Computational Modes, only the prescribed sets of shielding thicknesses may be used. Click *Apply*.



7. To compute and view the dose-depth report for this model, bring up the "Report and Graph Manger" by selecting *Analysis: Report & Graph Manager…* from the main menu. Make sure "Object Type" Satellite is selected. In the Styles pane, expand the Installed Styles folder and scroll down to the "SEET Radiation Dose Depth" report style and double-click it to launch the report. Note that the report may not generate instantly. It should look like the following:

Satellite-Satellite1

Shielding thickness (Mils)	Combined dose (rads)
8.250e+001	8.165e+003
2.325e+002	6.802e+002
4.575e+002	3.141e+002

8. The units of the shielding thickness can be changed by right-clicking on "(Mils)" in the report to expose an option menu. Go to *Shielding thickness: Units* to reveal the units panel. Uncheck "Use Defaults" and set the New Unit Value to "Millimeters (mm)". Click *OK*:

Satellite-Satellite1

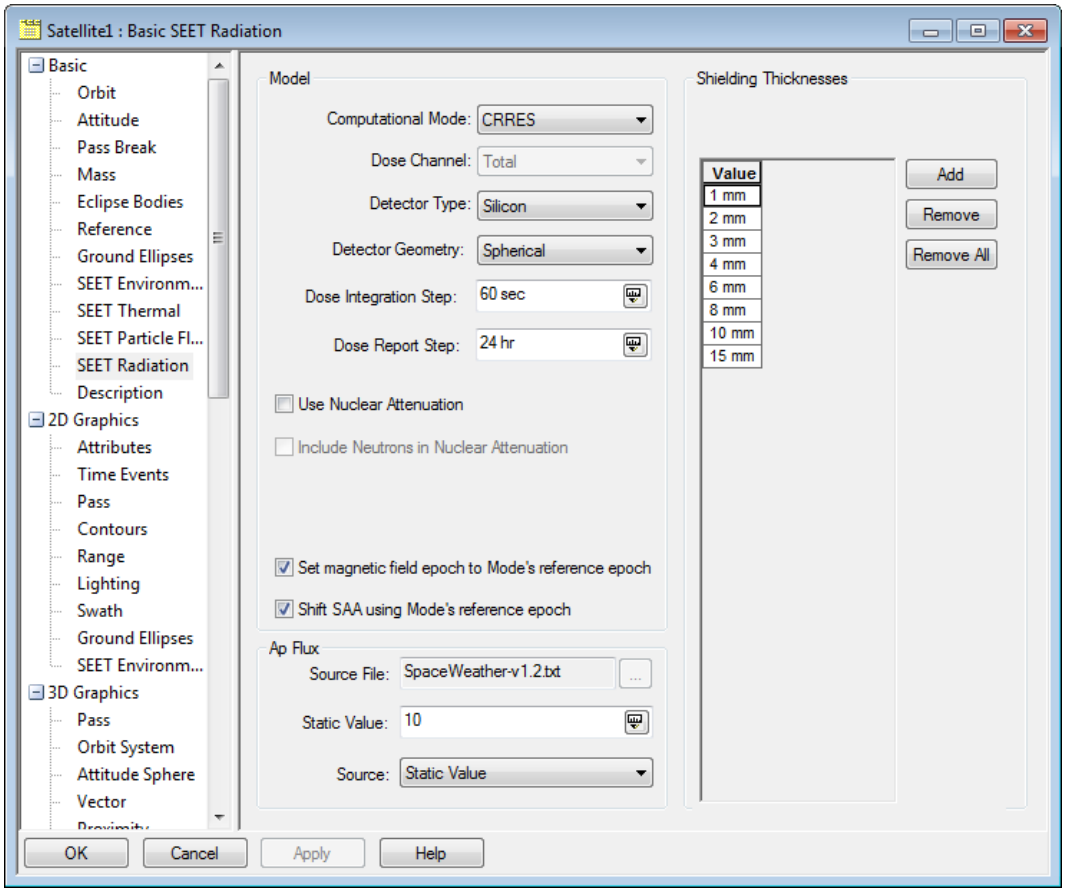
Shielding thickness (mm)	Combined dose (rads)
2.095e+000	8.165e+003
5.905e+000	6.802e+002
1.162e+001	3.141e+002

Configure the Radiation Environment for a high resolution dose-depth analysis

9. Now we will configure the Radiation Environment for a high resolution (*i.e.*, many depths) dose depth analysis and generate the corresponding report. On the satellite's Properties page, under "Basic", select "SEET Radiation". In the Model pane, for "Computational Mode", select "CRRES", leave the "Detector Type" as Silicon and set the "Detector Geometry" to "Spherical".

10. On the same page, click the *Remove All* button in the *Shielding Thicknesses* box. Click Add and enter "1 mm" in the text box that appears, then hit the Return or Enter key. Repeat this for the following set of shielding thicknesses: 2 mm, 3 mm, 4 mm, 6 mm, 8 mm, 10 mm, 15 mm.

11. Check the "Set magnetic field epoch…" and "Shift SAA …" boxes to override the environment magnetic field configuration, for greater SPENVIS compatibility. Leave "Dose Integration Step" at 60 sec and set "Dose Report Step" to 24 hours. Click *Apply*.



12. Return to the *Report & Graph Manager* configuration page. Next, from the list of "Installed Styles", right-click on the "SEET Radiation Dose Depth" report and select "Properties". Click on "Section 1" in the *Report Contents* box and click *Remove*. Go to the data-provider list on the left and expand the "SEET Radiation Dose Depth" object. Add *Shielding Thickness*, *Electron Dose*, *Electron-Brehsstrahlung Dose*, *Proton Dose* and *Combined Dose* to the *Report Contents* list (using the arrow button).

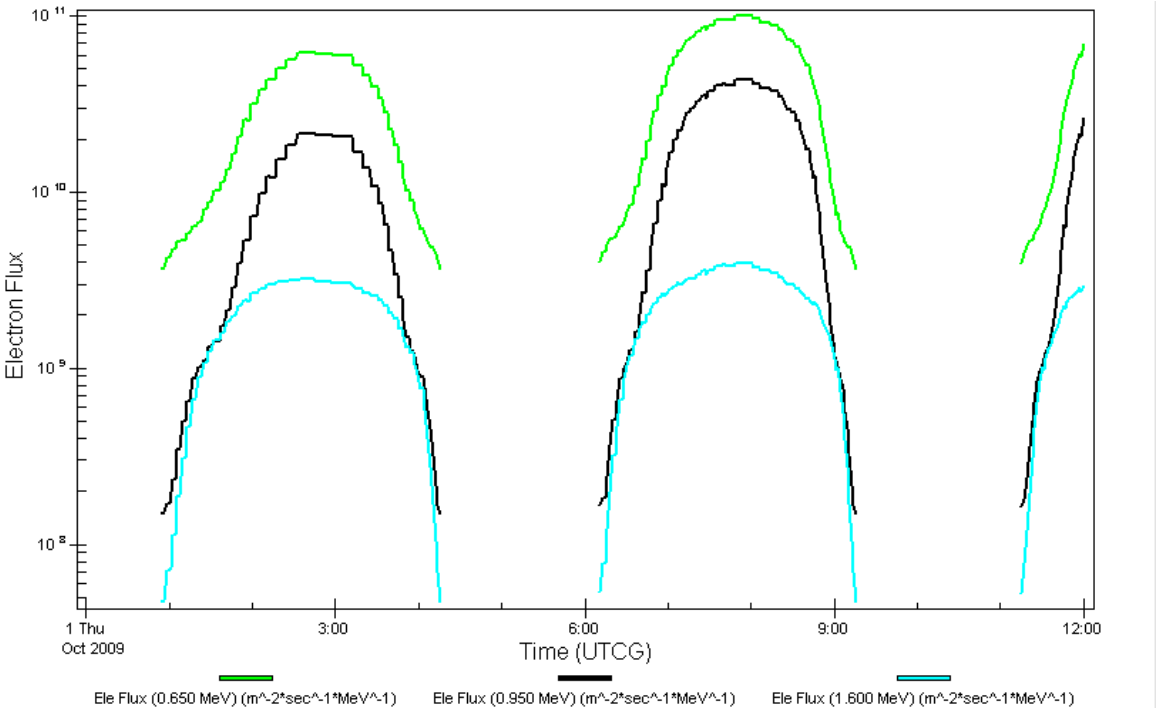
13. Highlight *Shielding Thickness* in the *Report Contents* box and then click the *Units* button. Clear the *Use Defaults* checkbox and then click on a New Unit Value of "Millimeters (mm)" and then click "OK". Click *Apply* in the *Reports & Graphs* window. A warning pop-up will be displayed asking to save this style under "My Styles"; click "OK". Click "OK" on the Properties page to close it. A "SEET Radiation Dose Depth" report icon should now be high-lighted under the "My Styles" folder. Double-click that icon or click the *Generate* button. Note that this report could take a couple minutes to generate depending on computer performance.

Satellite-Satellite1

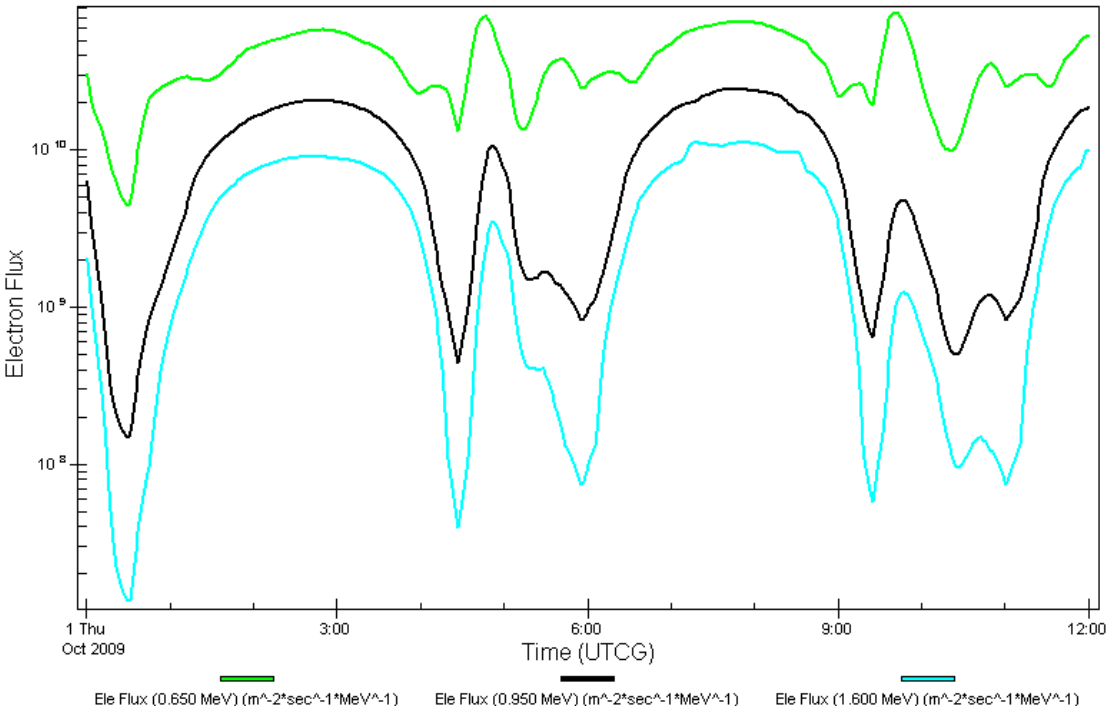
Shielding thickness (mm)	Electron dose (rads)	Electron-Bremsstrahlung dose (rads)	Proton dose (rads)	Combined dose (rads)
1.000e+000	1.721e+004	2.851e+001	4.071e+003	2.131e+004
2.000e+000	2.908e+003	1.273e+001	1.520e+003	4.440e+003
3.000e+000	5.014e+002	7.268e+000	1.083e+003	1.592e+003
4.000e+000	1.256e+002	4.988e+000	7.645e+002	8.951e+002
6.000e+000	1.454e+001	3.233e+000	4.438e+002	4.615e+002
8.000e+000	1.892e+000	2.582e+000	2.755e+002	2.800e+002
1.000e+001	2.841e-001	2.311e+000	2.175e+002	2.201e+002
1.500e+001	9.192e-006	1.860e+000	1.554e+002	1.572e+002

Configure the Radiation Environment for a min/max flux comparison

14. Return to the Report & Graph Manager page. Set the stop time to 1 Oct 2009 12:00:00.000 UTCG. In the Installed Styles folder, double-click on “SEET Radiation Electron Flux” to create the graph.



15. Go to the Satellite Properties page. Select “Computation Mode” *NASA* and click *Apply*. Return to the Report & Graph Manager page again and double-click “SEET Radiation Electron Flux”. Note the difference in scales and ranges of validity between the two graphs.


Electron Flux
10 10
10 9
10 8
1 Thu
Oct 2009
3:00
6:00
9:00
12:00
Time (UTCG)
Ele Flux (0.650 MeV) (m^-2*sec^-1*MeV^-1)
Ele Flux (0.950 MeV) (m^-2*sec^-1*MeV^-1)
Ele Flux (1.600 MeV) (m^-2*sec^-1*MeV^-1)